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Gertsch

INSTRUCTION BOOK
for
MODEL FM-4A
MICROWAVE FREQUENCY MULTIPLIER

RETURN TO
AEROSPACE DIV.

ELECTRONIC INSTRUMENTS

INSTRUCTION BOOK

For

MODEL FM-4~~B~~ A

MICROWAVE FREQUENCY MULTIPLIER

Gertsch

GERTSCH PRODUCTS, Inc.

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SECTION I - GENERAL DESCRIPTION

1. GENERAL

This instrument is based on an original circuit development. It is designed to extend the range of UHF Frequency Measuring equipment into the microwave region without loss of accuracy or stability.

2. PHYSICAL DESCRIPTION

The FM-4A is normally furnished in an aluminum carrying case with the following over-all dimensions:

Width	- 16 inches	Depth	- 21 1/2 inches
Height	- 12 inches	Weight	- 40 pounds

It is also available with fittings for rack mounting.

3. FUNCTION

This instrument is designed to measure and generate frequencies from 500 to 30,000 mc. An oscillator covering the fundamental range of 500-1000 mc drives an external crystal multiplier which provides harmonics to 30,000 megacycles. By means of control circuitry, the FM-4A Oscillator may be phase locked at the frequency of the UHF driving equipment plus or minus a 10 mc phase reference frequency. Means are provided for determining when the generated frequency matches the frequency fed into the instrument to be measured.

4. PERFORMANCE CHARACTERISTICS

A. Error with Internal Phase Reference .00005%
B. Error with External Phase Reference - zero.
C. Stability with Internal Phase Reference .00001%
D. Stability with External Phase Reference - zero.
E. Temperature Range -15° to $+55^{\circ}$ C.

5. EQUIPMENT SUPPLIED

A. Model FM-4A Microwave Frequency Multiplier complete with power cord, harmonic generator and mixer, coax cables, and instruction book.

B. Additional Equipment Required:
   1. Headphones
   2. UHF Frequency Generating Equipment. The FM-4A was specifically designed for use with the Gertsch Model FM-3 Frequency Meter or the Gertsch Model AM-1 VHF Interpolator.

6. POWER REQUIREMENTS

115/230 volts, 50-60 cycles, 150 VA maximum.

SECTION II - INSTALLATION

1. MOUNTING

The instrument may be mounted in a 19" rack by means of two special angle brackets which can be furnished with the instrument. These angles are attached to the instrument case by four 10-32 screws on each side. Provisions are made in all cases for the rack-mounting attachment. The angle brackets are inter-changeable to either right or left side, but should be mounted so that the instrument extends 14 1/2" back into the rack mount.

2. COOLING SYSTEM

The instrument is cooled by means of a pusher type fan. The air is taken in through the louvres in the side of the case and exhausted through the 4 1/2" hole in the back of the case. If the instrument is to be mounted in an enclosed type rack-mount or cabinet, provisions should be made in the back door of the mount or cabinet to provide a 4 1/2" clearance hole for the fan exhaust. Under normal operating conditions, the cooling fan requires no lubrication. If the instrument is operated under extremely dusty conditions, the fan should be checked periodically to make certain that the bearings are operating freely and dust has not accumulated in the fan itself. If the instrument is rack-mounted, precaution should be taken to assure that the set of louvres which fall behind the angle brackets are not obstructed to air flow. When rack-mounted, one set of louvres extends out beyond the rack mount and one set of louvres are behind the angle brackets.

3. CONNECTIONS

50 - 60 cycles, 115/230 volt AC power must be provided to the receptacle at the rear of the instrument. Make sure the proper connections are made to the power transformer for the particular input voltage being used. Normally, the FM-4A is wired at the factory for 115 volt operation. (See Figure 1 for this information.) Provisions have been made on the front panel for feeding the 1 megacycle input signal if desired. When the 1 megacycle input signal is fed in this manner, the 1 megacycle selector switch on the front panel must be placed in the external position. The external 1 megacycle fed to the instrument should have an amplitude of at least 1 volt peak. The Gertsch Model AM-1 VHF Interpolator has 1 megacycle output jack on its front panel and rear apron which are suitable to drive the FM-4A Microwave Frequency Multiplier. All FM-4A instruments are supplied with an external harmonic generator and mixer assembly (see Figure 2).

For all frequency measurements this assembly must be used in the configuration as shown in Figure 3. For frequency generation beyond the fundamental range of the instrument (500 - 1000 MC), the harmonic generator must be used.

SECTION III - OPERATION AND ADJUSTMENT

1. FUNCTION

This instrument generates frequencies from 500 to 1000 megacycles. Used in conjunction with the harmonic generator and mixer supplied, harmonics of these frequencies may be used to measure or generate frequencies from 500 to 30,000 megacycles. Harmonics of the unknown source may be used to measure frequencies below 500 mc.

2. DIAL CALIBRATION

In the Model FM-4A the dial is used only for a rough indication of frequency. The frequency of the oscillator may not exactly agree with the dial calibration. For example, it is possible for the dial to read slightly over 700 megacycles when measuring a frequency of 699.9 megacycles. The exact frequency is determined from the UHF source which controls the FM-4A.

3. WARM-UP TIME

The instrument may be operated as soon as the tubes become warm enough to conduct normally. A ten or fifteen minute warm-up period may simplify operation by reducing the rate at which the FM-4A oscillator frequency drifts when the oscillator is unlocked. No worthwhile improvement in the performance of the instrument should be expected from continuous operation.

4. METHOD OF OPERATION

Operation is described with the Gertsch Model FM-3 Frequency Meter as UHF driver. With the Model AM-1 VHF Interpolator, operation is exactly the same, except that the AM-1 may be used to provide 1 mc for the FM-4A phase reference.

A. To measure a Frequency.

(1) Place the power and stand-by switches in the ON position. Connect the UHF driver to the UHF driver input jack. If the Model AM 1 VHF Interpolator is used as the driver, connect the 1 megacycle output jack of the AM-1 to the 1 megacycle input of the FM-4A. Turn the 1 megacycle selector switch (4) to the external position. If the internal phase reference is to be used, check to see that the 1 megacycle selector is in the internal position.

(2) Connect the harmonic generator and mixer assembly as shown in Figure 3. If the signal to be measured may be conveniently brought to the FM-4A, the harmonic generator and mixer assembly may be fastened directly to the VIDEO IN or OUTPUT jack on the front panel, thereby eliminating one cable. In many cases it will be more convenient to have the harmonic generator and mixer assembly at a remote location.

(3) Place the lock control (2) in the BEAT position (fully counter-clockwise). A switch will click when the beat position is reached.

(4) Locate the frequency to be measured by tuning the FM-4A oscillator in the vicinity of the expected frequency as indicated on the dial. When the unknown frequency is approached, the beat indicator eye will be observed to close. The eye will open and close again as zero beat is passed and then open as signal is lost on the other side of zero beat. At the exact point of zero beat the eye will wink completely open and a squawk will be heard in the headphones. Tune the oscillator for an approximate zero beat. A precise zero beat is not necessary at this point.

(5) Measure the FM-4A oscillator frequency with the UHF driving equipment. It may be necessary to transfer the headphones to the driving equipment to do this. For example, if the FM-4A dial reads 970 mc and a Model FM-3 Frequency Meter is used as a driver, several beat notes will be found on the FM-3, one of them at 37.300 megacycles. Dividing 970 by 37.3 gives approximately 26, indicating that the 26th harmonic of the FM-3 is beating against the FM-4A. The exact frequency of the FM-4A would then be 26 x 37.300, or 969.8 megacycles. This is satisfactory agreement with the FM-4A dial calibration. The FM-3 should always be operated near the high end of its range, preferably between 35 and 40 mc. This is necessary to insure separation between high side and low side lock-in points on adjacent harmonics later in the procedure when the FM-4A frequency is locked to the FM-3. It is also helpful in identifying the harmonic of the FM-3 being used.

(6) In order to lock the FM-4A oscillator, the FM-3 must be adjusted to produce a signal exactly 10 megacycles above or below the FM-4A. In the examples to follow, the FM-3 will be operated on the high side. Equally satisfactory performance would be obtained with the FM-3 operated on the low side. In order to operate the FM-3 10 megacycles above 969.8 megacycles, it is necessary to add $\frac{10 \text{ mc}}{26}$ to the FM-3 reading. This is .3846 mc and the FM-3 should then be adjusted to 37.3000 + .3846 megacycles or 37.6846 megacycles. Set up this frequency on the FM-3 by going through the normal procedure for generating a frequency including calibration of the instrument. Some difficulty may be encountered if the FM-3

is set near a spurious response point. This will cause phase modulation of the FM-4A and noise when the FM-4A beats against the unknown. In the FM-3 this occurs when the low frequency dials are set near .000, .333, 500, .667, .750, or 1.000 mc. Frequencies within ±20 kc of these should be avoided. This can be done by operating the FM-3 low side instead of high side, or by choosing a different harmonic of the FM-3 to lock the FM-4A.

(7) Turn up the lock control (2) slowly while rocking the FM-4A tuning knob back and forth over about one megacycle. The control current meter will indicate when the FM-4A oscillator locks. A range will be found where the control current meter deflects rapidly as the tuning knob is turned. In this range the reactance control circuit is holding the oscillator frequency constant although the mechanical tuning control is moved. The edges of the lock-in range are reached when the control current reaches zero or a saturation level. The meter then suddenly jumps back to approximately 1 MA. Tune the FM-4A oscillator so that approximately 1 MA of control current is flowing with the oscillator in the lock-in range.

(8) Plug the headphones into the FM-4A. Tune the low frequency oscillator of the FM-3 until an exact zero beat against the unknown signal is obtained. Small detunings of either the FM-4A oscillator or the FM-3 high frequency oscillator should cause no change in the beat note. Check this to be sure that both oscillators are locked properly.

(9) Calculate the unknown frequency. Let F equal the frequency of the FM-3, AM-1 or other driver source. Let N equal the order of the harmonic used to lock the FM-4A. Let M equal the harmonic of the FM-4A matched against the unknown. Let X equal the unknown frequency. X = M(NF-10). If the FM-3 had been adjusted to 10 megacycles low side of the FM-4A, the unknown frequency would be X = MN(NF+10). For example, if the 10th harmonic of the FM-4A is matched to the unknown with the FM-4A tuned to approximately 970 megacycles and the 26th harmonic of the FM-3 is used to lock the FM-4A with the FM-3 set high side of the FM-4A and the frequency measured from the FM-3 when the exact zero beat with the unknown is reached is 37.6898 megacycles, then the unknown X = 10 (26 x 37.6846 -10). This is 9,698.0 megacycles. When used with the Gertsch Model AM 1 Interpolator as the UHF driver or with any other UHF source, the operation of the FM-4A in measuring a frequency is exactly the same. The UHF source must be used in the normal manner, first to measure a frequency of the FM-4A oscillator and then to generate a frequency exactly 10 megacycles away from this. If the source being measured is entirely unknown, refer to Part C of this Section for a method of identifying the harmonic of the FM-4A being used.

B. To Generate a Frequency.

(1) Place the power and stand-by switches in the ON position. Connect the UHF driver. If an external 1 megacycle signal is

to be used to drive the phase reference channel, turn the megacycle selector switch (4) to external and connect the 1 megacycle signal to the 1 megacycle jack. Divide the desired frequency by an appropriate harmonic factor to obtain the FM-4A instrument frequency. Stronger signals will be obtained if the lowest order harmonics are used and the FM-4A is operated near the high end of its range. For example, to generate a frequency of 10,812 mc, the 12th harmonic of 901 mc or the 11th harmonic of 982.091 megacycles should be used. Set the FM-4A dial roughly to this frequency.

(2) To generate frequencies above the fundamental range of the instrument (500 - 1000 MC), as in this example, the external harmonic generator must be used. This portion of the harmonic generator and mixer assembly (see Figure 4A) must be fastened to the OUTPUT connector on the front panel.

(3) Set the FM-3 or other UHF driver to generate the desired FM-4A frequency. To do this, divide the FM-4A frequency by an appropriate harmonic factor to obtain a suitable FM-3 frequency. Always operate the FM-3 near the high frequency end. See Part A-5. For example, to generate 982.091 mc on the FM-4A, a 25th harmonic of 39.2864 mc may be used on the FM-3. Set the FM-4A lock control (2) to the BEAT position. A switch will click when the BEAT position is reached. Plug the headphones into the FM-3 and tune the FM-4A dial until it approximately zero beats against the FM-3.

(4) Set the FM-3 to generate a frequency 10 megacycles above or below the desired FM-4A frequency. For this example, the FM-3 will be set high side. Since the 25th harmonic of the FM-3 is being used the FM-3 must be moved 10/25 of a megacycle. This is .4000 megacycles. The correct FM-3 frequency is then 39.6864 megacycles. Carefully calibrate the FM-3 and adjust it to generate this frequency. The same precautions mentioned in Part A-6 regarding FM-3 spurious responses should be observed.

(5) Rock the FM-4A tuning control back and forth over about one megacycle and slowly turn up the lock control (2) until a satisfactory lock-in is obtained as described in Part A-7. Adjust the tuning control for about 1 MA of control current in the lock-in range. The desired frequency is now available at the FM-4A harmonic generator output.

C. Measurement of the Frequency of an Entirely Unknown Source.

(1) Frequencies known to be above 500 megacycles. The method to be described requires only that the source be known to be above 500 megacycles. The procedure is as follows:

a. Use the standard measuring procedure of Section 4A. Start at 500 megacycles on the FM-4A oscillator and tune through the entire range noting the strongest responses. Go back to the first strongest beat note against the unknown signal. Measure this frequency carefully and call it F_1.

b. Tune upwards in frequency with the FM-4A oscillator dial until the next response having a beat note of approximately the same intensity is found. Measure this frequency and call it F_2. If only one response has been found of high signal intensity, the frequency being measured is in the fundamental range of the instrument, that is, 500 to 1000 megacycles and the frequency as read from the dial is the unknown frequency.

c. If two responses have been found, the first response must occur at a frequency $NF_1 = X$ where N is some integer representing the harmonic being used and X is the unknown frequency. Since the FM-4A was tuned to upward in frequency, to the next harmonic response, this response would occur at $(N-1)F_2 = X$, where N-1 indicates that the next lower harmonic in the FM-4A was being used when F_2 was measured. Solving these equations, we obtain $n = F_2/(F_2 - F_1)$. Having substituted the actual measurements into the equation, n will come out to be very close to some integral value. Choosing the closest integral value, it is then this integer times F_1 or $X = NF_1$ where N is the closest integral value to the n calculated by the equation above.

(2) Frequencies known to be below 500 megacycles. It is possible to measure frequencies below 500 megacycles with the FM-4A although it is not ordinarily convenient to do so. The UHF source required to drive the FM-4A can usually be used alone more easily to measure these frequencies. If it is desired to use the FM-4A for this purpose, the procedure is as follows:

a. Starting at 500 megacycles, tune the oscillator throughout its range, noting the loudest responses. Go back to the first loudest response, measure this frequency carefully and call it F_1.

b. Continue tuning upwards in frequency until the next response of approximately the same intensity has been obtained. Measure this and call it F_2. If no second response can be obtained, then the response is the second harmonic and the frequency of the unknown would be F_1 divided by 2. If a second response was obtained, the harmonic order can be calculated. The first response must have been obtained at a frequency $NX = F_1$ where N is an integer representing the harmonic of the source that was used in the measurement of F_1. A second response would occur at $(N+1)X = F_2$ indicating that the next higher harmonic of the source was

used in the second measurement. Solving these equations, we obtain $n = F_1/F_2 - F_1$). Substituting the actual measurements into this equation n will come out to be very close to some integral value. Choosing the closest integer to the small n obtained and substituting in the equation above, we obtain $X = F_1/N$.

D. Coupling

The FM-4A is equipped with type N connectors for the OUTPUT and VIDEO INPUT. These are coupled to the external harmonic generator and mixer assembly by means of the coax cables supplied. The harmonic generator and mixer assembly in turn may be coupled to the equipment being tested by means of coax (type N fitting), wave guide adapters, coupling loops or small antennas. If a very strong source is to be measured, some sort of attenuator or variable coupling device should be employed. An improvised antenna or coupling loop constructed on the end of a piece of co-axial line will be satisfactory for many applications. If maximum sensitivity or output is required from the FM-4A, a double stub tuner or other matching device may give a considerable improvement.

E. Spurious Responses

It is possible to get erroneous readings when using the FM-4A system by locking the FM-4A oscillator at some frequency other than 10 megacycles away from the UHF driver signal. This can occur when a harmonic of the FM-4A oscillator produces a 10 megacycle beat against a high order harmonic of the driver source. Such responses are more troublesome when the FM-4A is operated near its low frequency end. These lock-in signals are always much weaker than the correct one. If the lock control is advanced slowly while looking for the lock-in no difficulty will be encountered since the correct lock-in will always occur first. In the preceeding instructions for generating and measuring frequencies, the apparatus is always adjusted so that the FM-4A oscillator is approximately 10 megacycles away from the driver signal before lock-in is attempted. This is additional insurance against error from this source. After some experience is gained in operating the instrument, it may be safe to leave out some of the steps of the foregoing procedure and rely on the FM-4A dial in setting up the lock-in condition. If this is done, the operator must be careful to turn up the lock control slowly and select the strongest lock-in signal in the vicinity of the expected response. If there is any doubt, the full procedure should be followed.

F. Additional Notes on Operation

(1) Use of an auxiliary receiver. When measuring frequencies, the sensitivity and frequency range of the system may be greatly increased by the use of a sensitive external receiver or spectrum analyzer.

To do this, use the following procedure:

a. Couple both the unknown source and the FM-4A to the receiver. A variable coupling device may be helpful in obtaining maximum sensitivity.

b. With the FM-4A switched to stand-by, tune the receiver to the unknown signal.

c. Switch the FM-4A on and go through the normal measuring procedure, using the receiver as a beat note detector. Check each response on the receiver to be sure it is not an image. To do this, detune the receiver local oscillator slightly. If the beat note changes drastically, the response is an image and should be ignored. On a spectrum analyzer, check both responses to be sure the two signals are not separated by the image frequency. Both signals should be present at both responses, and there should be no responses which show only one signal.

SECTION IV - THEORY OF OPERATION

1. GENERAL

The FM-4A is a heterodyne type frequency measuring instrument. Frequencies are measured by heterodyning two signals together in a detector and adjusting them for zero difference in frequency. The fundamental range of the instrument is 500 through 1000 megacycles. Harmonics are used for complete coverage of the range from 500 to 30,000 megacycles. The basic principle involves locking a UHF oscillator to an accurately known frequency. The output of the oscillator is amplified and fed to an external crystal diode harmonic generator which, by reason of its non-linearity, generates the desired harmonics. The UHF oscillator is locked by means of an electronic feedback loop. The UHF oscillator is coupled to a crystal mixer where it beats against the UHF driver input. The difference frequency is fed to a 10 megacycle IF amplifier which provides very high gain at frequencies in the vicinity of 10 megacycles. The output of the 10 megacycle amplifier is compared against a stable 10 megacycle reference in a gated beam type phase detector. The output of the phase detector is a DC current which is fed to a crystal type variable reactance circuit which is coupled to the UHF oscillator. Since this is a phase sensitive control system, no steady state frequency error is possible. Hum modulation and other disturbances to the system result only in small amounts of phase modulation. The accuracy of the system is dependent upon the accuracy of the UHF driver input and the accuracy of the 10 megacycle reference signal sent to the phase detector. Since the frequency errors of the UHF driver and the 10 megacycle phase reference are additive, it can be shown that the percentage error introduced by the 10 megacycle reference channel is reduced by a factor of 50 in the worst case. A frequency multiplier chain is provided so that the 10 megacycle phase reference signal can be derived either from a 1 megacycle internal crystal oscillator or from a 1 megacycle signal fed into the unit from an external frequency standard. The output of the entire system described above consists of a very stable signal which is continuously variable from 500 to 1000 megacycles with harmonics of these frequencies generated by the external multiplier usable to 30,000 megacycles. This signal (500 - 1000 MC) is fed to the microwave output jack and to an external crystal detector. A signal may be taken from the microwave output jack for use in calibrating receivers or a transmitter signal may be fed into the video input jack and matched to the accurately known signal. The external detector crystal feeds an amplifier with a band width of over 200 kc. This amplifier is connected to the phone jack and to a diode frequency counter which operates an electron eye indicator. The purpose of the frequency counter and the electron eye indicator is to extend the range over which beat notes may be observed. The audio range is relatively very narrow

compared to the frequencies being measured, and at ordinary tuning speeds only a faint click is heard in the phones when the unknown frequency is passed. The frequency counter system is capable of detecting beat notes well over 10 times the highest audible frequency. Therefore, it is very useful in initially locating the unknown signal. It has the additional advantage of integrating the beat note. This may be very useful in measuring signals with frequency or amplitude modulation, intentional or otherwise. The headphones are much more sensitive than the electron eye indicator, and should be used for exact zero beating against stable signals. The external harmonic generator and mixer assembly of Figure 2 consists of two sub-assemblies shown in Figure 4.

Harmonics are generated by virtue of the non-linearity of the crystal, Y701. Mixing of an unknown frequency and harmonics of the FM-4A occurs in the mixer section by the action of Y702.

A. Operation of the Circuit in Measuring a Frequency

(1) The lock-in feedback loop is disabled by turning the lock control all the way counter-clockwise to the BEAT position. This removes screen voltage from the last IF amplifier. In this condition, the current flowing through the phase detector biases a variable reactance control to about the center of its range. The free running UHF oscillator is tuned until one of its harmonics matches the unknown signal.

(2) The UHF oscillator frequency is now measured by means of the UHF driver unit. Sufficient signal is fed back through the mixer to the driver unit to accomplish this.

(3) The harmonic of the UHF driver which was used to measure the FM-4A UHF oscillator is now offset 10 megacycles above or below the UHF oscillator by returning the UHF driver.

(4) The lock-in control loop is activated by turning up the lock control. The FM-4A oscillator is then retuned slightly until it locks. Lock-in is checked by rocking the FM-4A tuning control back and forth and noting that the control current swings in order to hold the oscillator to the correct lock-in frequency. The FM-4A oscillator is then set to the middle of the lock-in range.

(5) The UHF driver unit is now retuned slightly to bring the proper harmonic of the FM-4 oscillator to exactly the unknown frequency. The FM-4A detector system with headphones and electron eye beat note indicator is used to accomplish this.

(6) The unknown frequency is calculated from the calibration or measurement of the UHF driver input signal and the known frequency

relations in the FM-4A. When correctly locked, the UHF oscillator in the FM-4A must operate 10 megacycles above or below a harmonic of the driver input. The unknown frequency may then be calculated since it is a harmonic of the FM-4A oscillator frequencies. Simple formulas for this operation are provided in the operation and adjustment section of this instruction book.

B. Operation in Generating a Frequency.

(1) The proper FM-4A Frequency is calculated to give a harmonic at the desired frequency. The FM-4A tuning dial is set to approximately this frequency.

(2) The UHF driver is adjusted to give a harmonic at the desired FM-4A oscillator frequency and the FM-4A oscillator is adjusted to exactly this frequency.

(3) The UHF driver harmonic is moved exactly 10 megacycles by retuning the driver.

(4) The FM-4A lock control is turned up slowly and the tuning control is rocked until a proper lock-in is obtained.

(5) The desired frequency is now available at the FM-4A output jack. For frequencies above 1000 MC the external frequency multiplier must be attached to the OUTPUT jack.

2. DETAILED CIRCUIT DESCRIPTION

A. 10 Megacycle Phase Reference Channel (Figure 7).

This section consists of a 1 megacycle crystal oscillator and an amplifier-multiplier chain which gives a 10 megacycle output. V7A, one-half of a 12AT7 tube, is used as a crystal oscillator operating at 1 megacycle. The output of this is fed to V7B, the other half of the 12AT7, which operates as a quintupler. If the internal-external 1 megacycle switch is thrown to the external position, B+ is removed from V7A and the grid of V7B is switched to the external 1 megacycle input jack. Tube V8, a 6BH6, acts as a 5 megacycle amplifier. A double tuned transformer, T401, is used as the plate load. The secondary of T401 drives the grids of V9, a 12AT7 push-push doubler. In this circuit the two grids of the twin triode are driven in push-pull and the two plates are tied together. With this arrangement, a pulse of plate current flows to the plate tank circuit on every cycle of a 10 megacycle wave. The output is linked coupled from this tank circuit through co-axial fittings and cables to the phase detector in the 10 megacycle IF amplifier section. The entire oscillator section is enclosed in an aluminum can for shielding. This is to prevent blocking of

the high gain 10 megacycle IF system by signals radiated from this unit. All power leads going to the unit are filtered by bypass capacitors at the case and internal filter networks. V7A, the crystal oscillator, operates from a 150 volt regulated supply. The other stages operate from an unregulated source of approximately 150 volts.

B. 10 Megacycle IF amplifier (Figure 8).

This section consists of a high gain, 3 stage, tuned amplifier and a gated beam type phase discriminator. It is part of the feedback loop used to phase lock the 500 - 1000 megacycle UHF oscillator. V3, V4, and V5 are nearly identical stages using 6CB6 tubes. Permeability tuned coils are used. L301 is actually a tightly coupled RF transformer by which signals are coupled to the grid of V3 at a reasonably high impedance level. All coils are tuned to 10 megacycles with stray capacities except L304 and L306 where small quantities of additional capacity are required. Decoupling networks, consisting of 560 ohm resistors and .01 UFD capacitors, are used between each stage. A metallic shield is also used between each stage to prevent feedback and resultant oscillation. The output of V5 is fed to the limiter grid of V6, a type 6BN6 gated beam tube. The quadrature grid of the 6BN6 is fed from the 10 megacycle phase reference channel through L306 which acts as an RF transformer. The plate current of the 6BN6 depends on the phase relationship of the signals on the two control grids. Potentiometer R314 is used to adjust the 6BN6 steady state plate current. The output of the 6BN6 is fed through pin 5 of Jones plug P104 to the reactance control crystal in the UHF oscillator unit and to a phase correcting network which stabilizes the feedback loop. The shield over the 6BN6 tube is of a special material to provide shielding from magnetic fields within the instrument. The gain of the IF system is adjustable by means of R209, a potentiometer on the front panel. This potentiometer controls the screen voltage of V5 and therefore the gain of the tube. By means of this control, the IF gain can be reduced so that weak spurious lock-ins are rejected. The IF system is mounted on a channel shaped chassis which is closed by mounting on the main chassis for shielding against spurious 10 megacycle radiations. Power supply leads into the IF chassis are by-passed and filtered. Filament chokes are used between each stage to prevent feedback along the filament line.

C. UHF Microwave Section (Figure 9).

This section produces fundamental frequencies from 500 to 1000 mc. Tube V14 is a type 5675 pencil triode used as the UHF Oscillator. Resonant coaxial lines are used in the cathode and plate circuits. Energy is coupled from the plate of this tube to Y601, the UHF mixer crystal. Here the frequency of the oscillator beats against that of the UHF driver. The output of this mixer is fed to the IF amplifier. Y602, the reactance control

crystal, is also capacitively coupled to the plate of the oscillator. The effective RF impedance of this crystal changes as the control current through it is varied. This changes the amount of capacitive reactance as seen from the oscillator plate, thus giving control of the oscillator frequency. Control current through the control crystal, Y602 is metered by M201, the front panel control current meter. Output from the cathode of V14 is coupled to the cathode of V15, a type 5876 pencil triode amplifier. A concentric type filament choke is used for this tube. The plate circuit of V15 is tuned by a third resonant coaxial line. Output is coupled from the plate of V15 via L604 to the front panel OUTPUT connector. Non-contacting plungers are used to tune the three coaxial resonant lines. The three plungers are driven by a lead screw mechanism from the front panel tuning control. The carriage is coupled to the dial by means of flexible cables and eccentric pulleys. Eccentric pulleys are used to give a nearly linear frequency calibration on the dial. R605, R606 and R607 are 47 ohm resistors connected across the back end of the concentric lines to prevent undesirable resonance in this section. Silver plated screws are provided as trimmer capacitors on the three resonant coaxial lines.

D. Beat Note Amplifier (Figure 10).

This unit is used to match the FM-4A frequency to an unknown frequency. Signals from the crystal mixer are fed to the grid of V10, a 6AU6, which is used as the first video amplifier. L501, L502 and R501 are parasitic suppressors. The cathode tube is grounded at the crystal detector through the outer conductor of the coax. This is necessary to eliminate a ground loop in which hum would be induced by leakage flux from the power transformer. V10, V11 and V12 are video amplifiers having a band width somewhat over 200 kc. V11 and V12 are type 6AG5 tubes. V12 acts as a limiter on strong signals. Decoupling filters are used in the plate line between these stages to prevent feedback and reduce hum. V12 is capacitively coupled to the phone jack by C510. It is also coupled by C511 to the diode frequency counter. C511 is a small capacitor (56 mmfd) which couples the signal to Y501 a shunt crystal diode detector. Through Y501 an approximately constant amount of charge per cycle flows to C511. This results in a current through R517 and R518 which is approximately proportional to the frequency of the beat note. The voltage developed across these resistors is filtered by R519 and C513 and fed to the electron eye indicator tube. The sensitivity of this system is adjusted by varying R518, the front panel sensitivity control. At minimum sensitivity, about 200 kc is required to completely close the eye. The eye will close completely at about 12 kc with maximum sensitivity. As the FM-4A oscillator is tuned through a beat note against an unknown signal, the action of the frequency counter and electron eye indicator is as follows: with no signal, no voltage is produced by Y501 and the eye remains in the open position. When a beat note is encountered which is low enough to pass through the video amplifiers,

a voltage is produced by the counter circuit and the eye closes. As the system is tuned toward zero beat, the frequency fed to the counter decreases and the counter output voltage decreases, thus opening the eye. The eye becomes wide open at zero beat. If tuning is continued in the same direction, the eye will close again on the other side of zero beat and finally open when signal is lost because the frequency is too high to be passed by the video amplifier. The beat note will be heard on the phones when the eye winks open at zero beat. The eye is intended mainly to locate the beat note and bring it down to the audio range. The eye may be used for the final zero beat in case of a noisy or modulated signal, when the integrating action of R519 and C513 will be useful. A sensitivity control, R518, is provided so that sensitivity may be increased for this purpose.

E. Power Supply (Figure 11).

The B+ supply is conventional full wave rectifier using a type 5U4G tube. Both the fan and the power transformer T201, are rated for 50 or 60 cycle operation. The stand-by switch interrupts all B+ power. RC filtering is used. A regulated 150 volt output is used for the crystal oscillator in the 10 mc phase reference section and for the UHF oscillator. 260 volts unregulated is fed to the UHF amplifier and 150 volts unregulated is fed to the rest of the unit. Jones plug connections for the various removable units are shown on the power supply schematic.

F. External Harmonic Generator and Mixer Assembly (Figure 5).

The external harmonic generator and mixer assembly of Figure 2 consists of two sub-assemblies shown schematically in Figure 5.

Harmonics are generated (Figure 5A) by virtue of the non-linearity of the crystal, Y701. The input section provides a low impedance shunt path for the harmonics thus preventing loss back into the driving source. The choke on the output side provides a DC return path for the rectified crystal current. This choke has low reactance to the driving frequency so that various loads may be put on the harmonic generator without much danger of a high impedance to the driving frequency being built up at the output side of the crystal. This would cause the driving power that the crystal would receive to be greatly decreased with a corresponding reduction in output harmonics. The choke also serves to reduce the amplitude of the fundamental frequency and low order harmonics without affecting the higher order harmonics seriously.

Mixing of the unknown frequency and the FM-4A output occurs in Y702 (Figure 5B). The input choke presents a low impedance to the fundamental and low order harmonics from the FM-4A thereby reducing the noise output of the mixer due to these frequencies. The output circuit presents a low impedance to unwanted harmonics which would otherwise be fed to the video amplifier in the FM-4A.

Since this system is designed to be broad band, the performance at any given frequency can generally be improved by using some tuning in the form of a stub ahead of the mixer. Harmonic generator performance can be improved in a similar manner.

SECTION V - MAINTENANCE

1. GENERAL

A. Removable Units. All sections except the power supply may be easily removed from the main chassis for repair or replacement, if necessary. Electrical connectors are provided with long cables so that units may be unfastened and turned over for measurements. The 10 mc phase reference unit is somewhat less accessible than the rest due to stricter shielding requirements. Tubes may be replaced by removing the top cover from this unit. To test or remove other components, the entire can may be removed.

B. Location of Trouble. Troubles may usually be isolated to a single unit by measurement at the terminals of the units. The oscillator multiplier 10 mc reference unit may be checked by measuring the signal at its output jack. Three to four volts of 10 mc signal should be measured when the internal-external switch is on Internal or when the switch is on External and a suitable 1 mc input is fed in. A wide band oscilloscope or a VTVM with an RF probe may be used to check this. The IF Amplifier section may be checked by disconnecting the phase reference from J302, the reference jack, and connecting the 10 mc signal to J301, the input jack. The 10 mc phase reference unit may be used to provide this signal, although a tunable 10 mc signal generator is better. The control current meter should show a deflection when signal is fed into this jack. If the frequency of the 10 mc signal is varied over several hundred kc, the control current meter should change deflection with the frequency of the test signal. This is because the 6BN6 gated beam tube will act as a frequency discriminator if the phase input is disconnected. If internal checks are made on the IF Amplifier, the gain should be about 30 db per stage. When checking the IF amplifier it should be remembered that the gain of V5, the third stage of the IF amplifier, is varied by the front panel lock control. This stage will pass little or no signal with the control in the BEAT position. Rough checks may be made by removing a tube and connecting the RF probe of the VTVM to pin one on the socket. Some detuning will result unless the probe exactly matches the tube input capacitance, but a useable signal should be found. Operation of the UHF oscillator amplifier system may be checked by measuring the DC current rectified by the diode detector crystal. This crystal is located in the external "T" fitting. With the external harmonic generator and mixer assembly connected to the instrument, a milliameter connected from C609 to chassis ground should read no less than 10 ma. for any position of the main tuning dial. The UHF oscillator alone may be checked at the UHF driver input jack. If a Gertsch Model FM-3 Frequency Meter or Model AM-1, VHF Interpolator is used, use this instrument to locate beat notes against the UHF oscillator. Voltage checks may be made on the oscillator and amplifier by removing the cover from this unit. Open filaments may also be detected by feeling the cathode end of each tube for heat. To eliminate any shock

hazard, the STANDBY-OPERATE switch should be in the STANDBY position when doing this. The video amplifier section may easily be checked since the input tube is usually somewhat microphonic. If this tube is tapped, the eye should wink, particularly if the sensitivity control is turned up, and loud ringing noises should be heard in the headphones. Further checks may be made by disconnecting the cable from the video input jack and injecting an audio signal from a suitable oscillator. The power supply section may be checked by turning the unit on its side and measuring voltages under the chassis. As a preliminary check, the voltage regulator tube should light when the POWER and STANDBY switches are both in the ON position. When the trouble is isolated to a specific unit, voltage and resistance measurements within that unit will usually lead to the faulty component without difficulty. Time will usually be saved by a systematic procedure in doing this. First, locate the unit at fault, then the stage, finally, the component of that stage.

2. ADJUSTMENTS

A. 10 Megacycle Oscillator Multiplier Unit. This unit should require adjustment only when critical components are replaced. Satisfactory operation will probably be obtained without adjustments after replacing vacuum tubes, but alignment should be checked if any difficulty is encountered. A hole is provided in the side panel of the instrument and in the oscillator multiplier can for the adjustment of C402, the crystal trimmer. Since any error in this channel is divided by 50 before reaching the output of the instrument, this adjustment is not too critical and should not require periodic checking. If adjustment is required, operate the unit with the one megacycle selector switch in the internal position. Connect the 10 megacycle output jack, J402, to a suitable receiver where it can be compared against WWV or some other suitable frequency standard. If a counter rated for 10 megacycles is available, the signal at J402 should be sufficient to drive it. Adjust C402 until exactly 10 megacycles is obtained at the 10 megacycle output jack. To tune the other stages of this unit, feed one megacycle from a signal generator to the one megacycle input jack. Turn the selector switch to the external position. Measure the signal at J402, the 10 megacycle output jack, with an oscilloscope or vacuum tube voltmeter equipped with an RF probe. If no such instrument is available, the lead of a crystal diode may be inserted in J402 and the resulting DC output measured a suitable voltmeter. Turn down the input from the signal generator until the stages are operating well below saturation. The output meter must follow any changes in the input level. Adjust the two tuning slugs in T401, the IF transformer, and the single slugs in L402 and L403 for a maximum 10 megacycle output.

B. IF Amplifier. To adjust this unit, a 10 megacycle signal generator with a variable output attenuator is required. Adjustments can be made by reference to the control current meter on the front panel. First, disconnect both the phase reference input and the IF input from the

unit. Adjust R314, the bias control for the gated beam tube, for approximately 1 MA of current as indicated by the front panel meter and turn the lock control all the way up. Adjust the signal generator to exactly 10 megacycles and connect it to the J301, the IF input jack. Adjust L306, the discriminator phase reference coil, for maximum reading on the front panel control current meter. This should be done with J302, the phase reference input disconnected. Turn down the 10 megacycle signal generator output until the front panel control current meter follows the motion of the signal generator output control. Tune the slugs in L301, L302, L303 and L304 for maximum indication on the meter. If saturation is reached at any point, reduce the 10 megacycle input. This is a single tuned amplifier, and all three IF stages should be tuned at 10 megacycles. Turn up the 10 megacycle input until saturation is reached. Connect the cable to the phase reference unit, and turn the 1 mc selector to external with no signal fed to the 1 mc jack. Adjust the slug in L306 for approximately 1 MA control current. If adjustments are carefully made according to the above procedure, this unit should operate satisfactorily.

UHF Unit. Adjustment of this unit will probably be required when tubes or other components are replaced. The trimmer capacitors should always be adjusted first and other adjustments left alone if satisfactory performance is then obtained. The trimmers consist of silver plated screws which protrude into the oscillator and amplifier compartments. The trimmers should always be adjusted at the low frequency end of the dial. This is not the normal procedure for lumped constant tuned circuits, but it must be remembered that this unit is tuned by coaxial lines and the plunger adjustments are most sensitive at the high frequency end. To adjust this unit, a voltmeter and a frequency meter covering the UHF range such as the Gertsch FM-3 or Gertsch Model AM 1 Interpolator, are required. Attach the harmonic generator and mixer assembly to the OUTPUT jack of the FM-4A. Do not connect this assembly to the VIDEO INPUT jack, but instead connect a voltmeter to the video plug of the assembly. A DC voltmeter connected at this point can be used as a tuning indicator. Energize the unit and set the FM-4A UHF oscillator so that the frequency dial reads 500 megacycles. Connect the FM-3 or other UHF frequency meter to the UHF input jack. Measure the UHF oscillator frequency with this instrument by the method of checking two adjacent responses so that the harmonic order may be determined. The exact frequency of the FM-4A oscillator can then be calculated. Set the UHF frequency meter to produce a harmonic at exactly 500 megacycles. 20 megacycles is a convenient fundamental setting for the FM-3 or AM-1. Tune the oscillator to exactly match this frequency by tuning the trimmer at the plate end of the tube. Go back and recheck by the two frequency method if there is any doubt about the order of the FM-3 harmonic being used. Tune the oscillator cathode trimmer and the amplifier plate trimmer for maximum output on the tuning indicator connected to J604. Go back and retune the oscillator plate trimmer to exactly 500 megacycles. Repeat these steps until no further adjustment is necessary. If for any reason the plungers require re-adjustment, the Allen

screws holding the drive rods must be loosened and the plungers adjusted in exactly the same manner as the trimmers except at a frequency of 1000 megacycles. The oscillator plate plunger will have the most effect on frequency and its position relative to dial movement should be left alone if possible. Tracking of the dial should be checked at many points. This can easily be done by setting the driving frequency meter at 20 megacycles and locating the beat note at each 20 megacycle mark along the dial. The dial should always be moved in the same direction to eliminate back-lash when making this check. If the oscillator cannot be adjusted to track the dial, the dial adjustments must be changed. To do this, loosen the Allen screws in the dial and set it right on at 500 megacycles. Tune to 1000 megacycles and notice whether the dial has moved too little or too much. This may be varied by loosening the set screw which clamps the drive cable to the sliding carriage. To increase the dial motion, move the cable in the direction of increasing dial reading. Then clamp the cable and go back to 500 megacycles. Set the dial exactly on at this frequency by rotating the dial on its shaft, and recheck at 1000 megacycles. Continue this process until the correct amount of dial motion is obtained. Now go back and check other points throughout the range. It must be remembered that this dial is used only for a rough frequency calibration, and small errors can be tolerated. Adjustments to the plungers and dial drive should be avoided unless necessary. If the dial drive cable must be replaced, try to do this without changing the relative position of the dial and eccentric pulleys on the shaft. After replacing the cable, set the oscillator to exactly 1000 megacycles by means of the FM-3 or other UHF frequency meter and adjust the position of the new cable relative to the carriage so that the dial reads exactly 1000 megacycles. The calibration of the dial should then check reasonably well at other frequencies. If excess back-lash is found in the drive the spring tension on the cable may be at fault. Too much tension will cause excessive friction at the pulleys while too little tension will cause sag in the cables.

SECTION VI - PARTS LIST

Circuit Ref.	Description
R201	Resistor: wire wound, 75 ohms, ±10%, 10 W.
R202	Resistor: wire wound, 2000 ohms, ±10%, 20 W.
R203	Resistor: wire wound, 2250 ohms, ±10%, 20 W.
R204	Resistor: wire wound, 2000 ohms, ±10%, 10 W.
R205	Resistor: wire wound, 2500 ohms, ±10%, 10 W.
R206	Resistor: wire wound, 2000 ohms, ±10%, 10 W.
R207	Resistor: composition, 1500 ohms, ±10%, 1/2 W.
R208	Resistor: composition, 100 ohms, ±10%, 1/2 W.
R209	Potentiometer: composition, 50 k, ±10%, 2 W.
R301	Resistor: composition, 8200 ohms, ±10%, 1/2 W.
R302	Resistor: composition, 270 ohms, ±10%, 1/2 W.
R303	Resistor: composition, 560 ohms, ±10%, 1/2 W.
R304	Resistor: composition, 8200 ohms, ±10%, 1/2 W.

Circuit Ref.	Description
R305	Resistor: composition, 270 ohms, ±10%, 1/2 W.
R306	Resistor: composition, 560 ohms, ±10%, 1/2 W.
R307	Resistor: composition, 8200 ohms, ±10%, 1/2 W.
R308	Resistor: composition, 270 ohms, ±10%, 1/2 W.
R309	Resistor: composition, 10,000 ohms, ±10%, 1/2 W.
R310	Resistor: composition, 560 ohms, ±10%, 1/2 W.
R311	Resistor: composition, 4700 ohms, ±10%, 1/2 W.
R312	Resistor: composition, 10,000 ohms, ±10%, 1/2 W.
R313	Resistor: composition 1000 ohms, ±10%, 1/2 W.
R314	Potentiometer: wire wound, 1000 ohms, ±10%, 2 W.
R315	Resistor: composition 6800 ohms, ±10%, 1/2 W.
R316	Resistor: composition, 10,000 ohms, ±10%, 1/2 W.
R402	Resistor: composition, 100 ohms, ±10%, 1/2 W.
R403	Resistor: composition, 1000 ohms, ±10%, 1/2 W.

Circuit Ref.	Description
R404	Resistor: composition, 47 ohms, ±10%, 1/2 W.
R405	Resistor: composition, 470 k, ±10%, 1/2 W.
R406	Resistor: composition, 270 ohms, ±10%, 1/2 W.
R407	Resistor: composition, 100 k, ±10%, 1/2 W.
R408	Resistor: composition, 1000 ohms, ±10%, 1/2 W.
R409	Resistor: composition, 15 k, ±10%, 1/2 W.
R410	Resistor: composition, 1000 ohms, ±10%, 1/2 W.
R411	Resistor: composition, 470 ohms, ±10%, 1/2 W.
R412	Resistor: composition 150 k, ±10%, 1/2 W.
R413	Resistor: composition, 150 k, ±10%, 1/2 W.
R414	Resistor: composition, 100 ohms, ±10%, 1/2 W.
R415	Resistor: composition, 1000 ohms, ±10%, 1/2 W.
R416	Resistor: composition 47 ohms, ±10%, 1/2 W.
R417	Resistor: composition 47 ohms, ±10%, 1/2 W.

Circuit Ref.	Description
R501	Resistor: composition, 47 ohms, ±10%, 1/2 W.
R502	Resistor: composition, 470 k, ±10%, 1/2 W.
R503	Resistor: composition, 1000 ohms, ±10%, 1/2 W.
R504	Resistor: composition, 22 k, ±10%, 1/2 W.
R505	Resistor: composition, 82 k, ±10%, 1/2 W.
R506	Resistor: composition, 4700 ohms, ±10%, 1/2 W.
R507	Resistor: composition, 470 k, ±10%, 1/2 W.
R508	Resistor: composition, 33 k, ±10%, 1/2 W.
R509	Resistor: composition, 150 k, ±10%, 1/2 W.
R510	Resistor: composition, 4700 ohms, ±10%, 1/2 W.
R511	Resistor: composition, 4700 ohms, ±10%, 1/2 W.
R512	Resistor: composition, 22 k, ±10%, 1/2 W.
R513	Resistor: composition, 68 k, ±10%, 1/2 W.
R514	Resistor: composition, 68 k, ±10%, 1/2 W.

Circuit Ref.	Description
R515	Resistor: composition, 47 k, ±10%, 1/2 W.
R516	Resistor: composition, 47 k, ±10%, 1/2 W.
R517	Resistor: composition, 22 k, ±10%, 1/2 W.
R518	Potentiometer: composition 500 k, ±10%, 1 W.
R519	Resistor: composition, 1 megohm, ±10%, 1/2 W.
R520	Resistor: composition, 1 megohm, ±10%, 1/2 W.
R521	Resistor: composition, 47 ohms, ±10%, 1/2 W.
R601	Resistor: composition, 47 ohms, ±10%, 1/2 W.
R602	Resistor: composition, 5600 ohms, ±10%, 1/2 W.
R603	Resistor: composition, 270 ohms, ±10%, 1/2 W.
R605	Resistor: composition, 47 ohms, ±10%, 1/2 W.
R606	Resistor: composition, 47 ohms, ±10%, 1/2 W.
R607	Resistor: composition, 47 ohms, ±10%, 1/2 W.
R608	Resistor: composition, 150 ohms, ±10%, 1/2 W.

Circuit Ref.	Description
C201	Capacitor: electrolytic, 80 ufd., 500 wvdc, Cornell-Dubilier UP 8050
C202 C203	Capacitor: dual electrolytic, 40-40 ufd., 450 wvdc, Sprague TVL 2764
C204 C205	Capacitor: dual electrolytic, 20-20 ufd., 450 wvdc, Sprague TVL 2755
C206	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C207	Capacitor: paper, 1.0 ufd., 200 wvdc, Aerovox P-82
C301	Capacitor: disc ceramic .01 ufd., 500 wvdc.
C302	Capacitor: disc ceramic, 100 uuf, 500 wvdc.
C303	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C304	Capacitor: disc ceramic .01 ufd., 500 wvdc.
C305	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C306	Capacitor: disc ceramic, 100 uuf., 500 wvdc.
C307	Capacitor: disc ceramic, 3 uuf., 500 wvdc. NPC
C308	Capacitor: disc ceramic, .01 ufd., 500 wvdc.

Circuit Ref.	Description
C309	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C310	Capacitor: disc ceramic, 100 uuf., 500 wvdc.
C311	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C312	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C313	Capacitor: disc ceramic, 1.5 uuf., 500 wvdc.
C314	Capacitor: disc ceramic, 5 uuf., 500 wvdc.
C315	Capacitor: ceramic feedthrough, 1000 uuf., 500 wvdc.
C316	Capacitor: ceramic feedthrough, 1000 uuf., 500 wvdc.
C317	Capacitor: ceramic feedthrough, 1000 uuf., 500 wvdc.
C318	Capacitor: ceramic feedthrough, 1000 uuf., 500 wvdc.
C319	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C320	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C321	Capacitor: disc ceramic .01 ufd., 500 wvdc.
C322	Capacitor: disc ceramic, .01 ufd., 500 wvdc.

Circuit Ref.	Description
C323	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C324	Capacitor: disc ceramic, 100 mmfd., 500 wvdc.
C325	Capacitor: disc ceramic, .01 mfd, 500 wvdc.
C401	Capacitor: disc ceramic, 10 uuf., 500 wvdc.
C402	Capacitor: ceramic trimmer, 3-12 uuf., 500 wvdc.
C403	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C404	Capacitor: disc ceramic, 100 uuf, 500 wvdc.
C405	Capacitor: disc ceramic, .005 ufd., 500 wvdc.
C406	Capacitor: disc ceramic, 62 uuf., 500 wvdc.
C407	Capacitor: disc ceramic, .005 ufd., 500 wvdc.
C408	Capacitor: disc ceramic, 100 uuf., 500 wvdc.
C409	Capacitor: disc ceramic, .005 ufd., 500 wvdc.
C410	Capacitor: disc ceramic, .005 ufd., 500 wvdc.
C411	Capacitor: disc ceramic, 50 uuf., 500 wvdc.

Circuit Ref.	Description
C412	Capacitor: disc ceramic, 100 uuf., 500 wvdc.
C413	Capacitor: disc ceramic, 100 uuf., 500 wvdc.
C414	Capacitor: disc ceramic, 100 uuf., 500 wvdc.
C415	Capacitor: disc ceramic, .005 ufd., 500 wvdc.
C416	Capacitor: disc ceramic, .005 ufd., 500 wvdc.
C417	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C418	Capacitor: ceramic feedthrough, 1000 uuf., 500 wvdc.
C419	Capacitor: ceramic feedthrough, 1000 uuf., 500 wvdc.
C420	Capacitor: ceramic feedthrough, 1000 uuf., 500 wvdc.
C421	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C422	Capacitor: disc ceramic, .005 ufd., 500 wvdc.
C501	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C502	Capacitor: disc ceramic, 120 uuf., 500 wvdc.
C503	Capacitor: paper, .01 ufd., 200 wvdc. Aerovox P 82

Circuit Ref.	Description
C504 C505 C509	Capacitor: triple electrolytic, 10-10-10 ufd., 300 wvdc, Aerovox AFH 3-22
C506	Capacitor: paper, .05 ufd., 200 wvdc, Aerovox P-82
C507	Capacitor: paper, 0.1 ufd., 200 wvdc, Aerovox P-82
C508	Capacitor: paper, .05 ufd., 200 wvdc, Aerovox P-82
C510	Capacitor: paper, 1.0 ufd., 200 wvdc, Aerovox P-82
C511	Capacitor: disc ceramic, 50 uuf., 500 wvdc.
C512	Capacitor: paper, .05 ufd., 200 wvdc. Aerovox P-82
C513	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C514	Capacitor: disc ceramic, .01 ufd., 500 wvdc.
C601	Capacitor: ceramic feedthrough, 1000 uuf., 500 wvdc.
C602	Capacitor: ceramic feedthrough, 1000 uuf., 5000 wvdc.
C603	Capacitor: coupling, GPI Special
C604	Capacitor: trimmer, GPI Special

Circuit Ref.	Description
C605	Capacitor: trimmer, GPI Special
C606	Capacitor: bypass, GPI Special
C607	Capacitor: coupling, GPI Special
C608	Capacitor: trimmer, GPI Special
C609	Capacitor: feedthrough 1000 mmfd, 1000 wvdc.
C610	Capacitor: disc ceramic, 1500 uuf., 500 wvdc.
C611	Capacitor: disc ceramic, 1500 uuf., 500 wvdc.
C612	Capacitor: disc ceramic, .005 mfd, 500 wvdc.
T201	Transformer: power, Triad R-16A
T401	Transformer: discriminator, 4.5 mc, Merit TV-109.
L201	Inductor: RF choke, GPI Special
L401	Inductor: RF choke Standard Coil XM800 2.5 MH.
L402	Inductor: GPI Special CTC, LS-7 Form
L403	Inductor: GPI Special CTC LS-5 Form

Circuit Ref.	Description
L404	Inductor: RF choke, Standard Coil, XM800 2.5 MH.
L405	Inductor: filament choke, GPI Special.
L406	Inductor: filament choke, GPI Special.
L501	Inductor: RF choke, GPI Special.
L502	Inductor: RF choke, GPI Special.
L503	Inductor: RF choke, GPI Special.
L601	Inductor: RF choke, GPI Special
L602	Inductor: filament choke GPI Special.
L603	Inductor: RF choke, GPI Special.
L604	Inductor: RF choke, GPI Special.
L605	Inductor: RF choke, GPI Special.
V1	Tube: 5U4G
V2	Tube: OD3/VR150
V3	Tube: 6CB6
V4	Tube: 6CB6
V5	Tube: 6CB6

Circuit Ref.	Description
V6	Tube: 6BN6
V7	Tube: 12AT7
V8	Tube: 6BH6
V9	Tube: 12AT7
V10	Tube: 6AU6
V11	Tube: 6AG5
V12	Tube: 6AG5
V13	Tube: 6E5
V14	Tube: 5675
V15	Tube: 5876
Y401	Quartz Crystal: 1 MC
Y501	Crystal: IN52
Y601	Crystal: G7A
Y602	Crystal: IN95
Y701	Crystal: IN21B
Y702	Crystal: IN23B
B201	Motor: fan, Barber-Colman DYAB 569-3 YAR 328 Blade YAB 1266 Bushing.
M201	Panel Meter 0-3 ma.

LIST OF ILLUSTRATIONS

1. 115/230 Voltage Connections
2. Harmonic Multiplier and Mixer Assembly
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4. Harmonic Generator and Mixer Sub-Assembly
5. Harmonic Generator and Mixer Sub-Assembly Schematic
6. FM-4A Block Diagram
7. Oscillator - Multiplier Schematic
8. 10 MC IF Amplifier Schematic
9. H. F. Oscillator Schematic
10. Beat Note Amplifier Schematic
11. Power Supply Schematic
12. Inter-Connecting Cabling Diagram

The FM-4A is equipped with a dual primary power transformer rated at 115 - 230 volts AC, 50 - 60 cycle. The instrument is normally shipped from the factory wired for 115 volts AC. In order to change the instrument to 230 volt operation the following changes have to be made.

The tie point lug located underneath the main chassis has four lugs, No. 1 being closest to the front panel. For 115 volt operation there are jumper wires connected between 1 and 3, 2 and 4. To operate on 230 volts disconnect these jumpers and place a jumper between 2 and 3.

Caution: Do not change the position of the other wires connected to the tie lug.

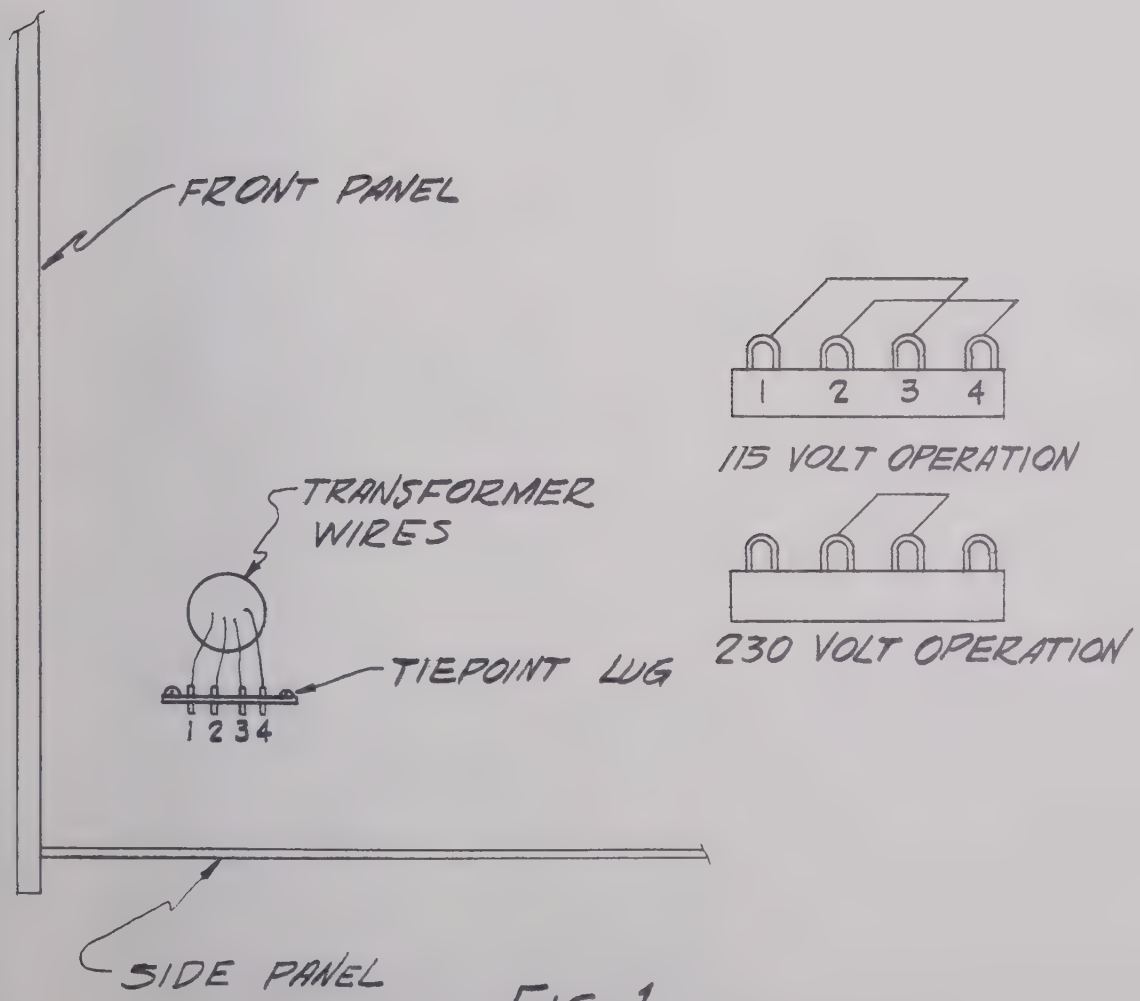
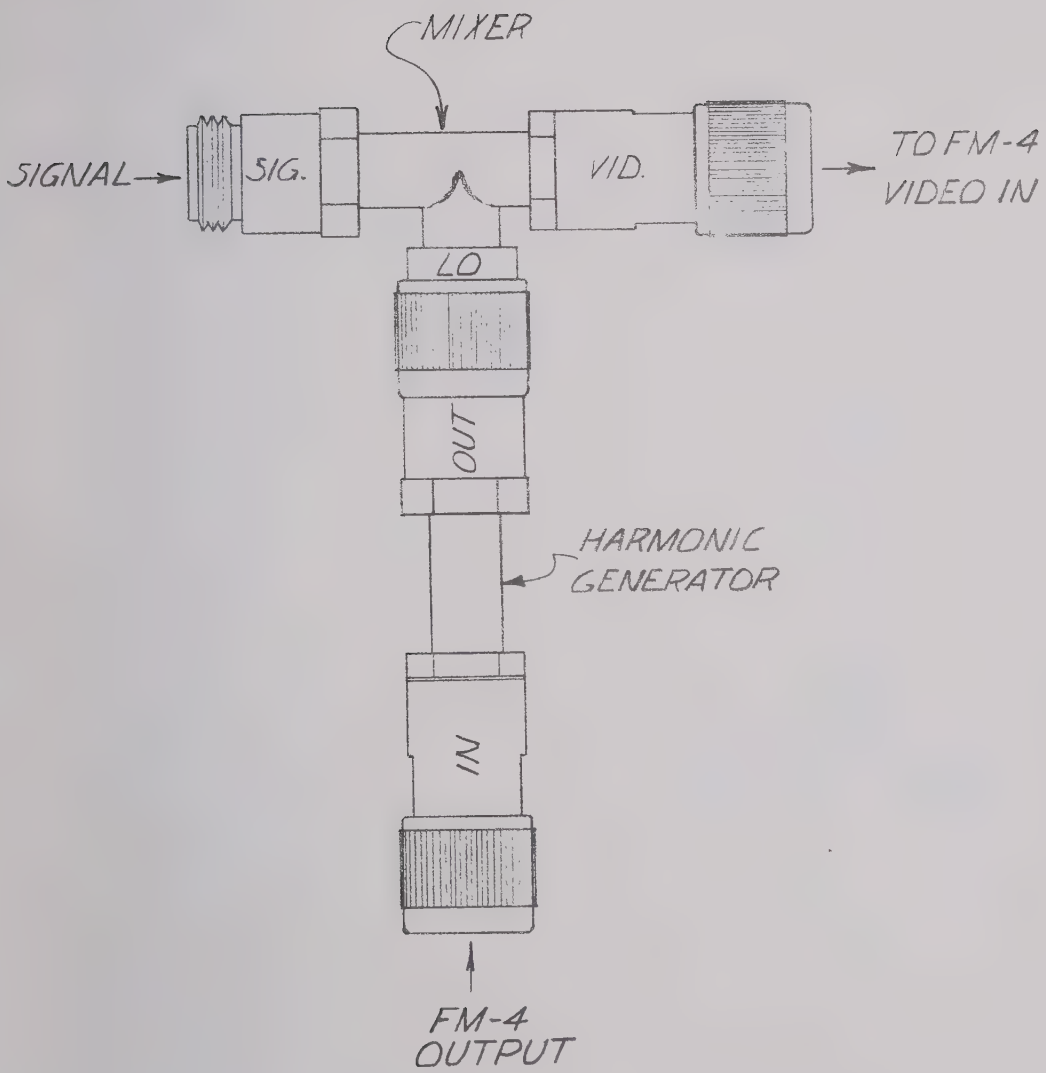
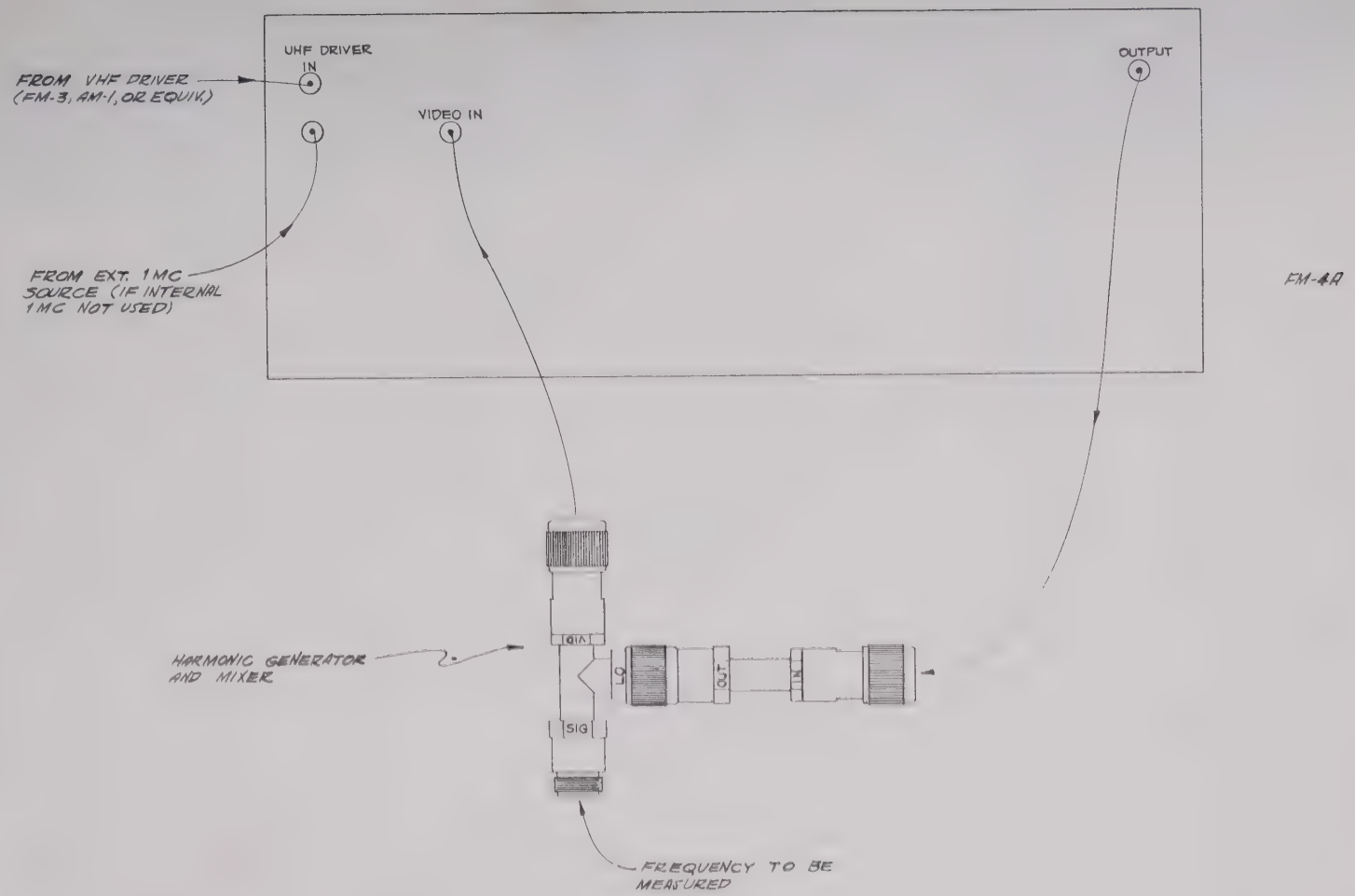
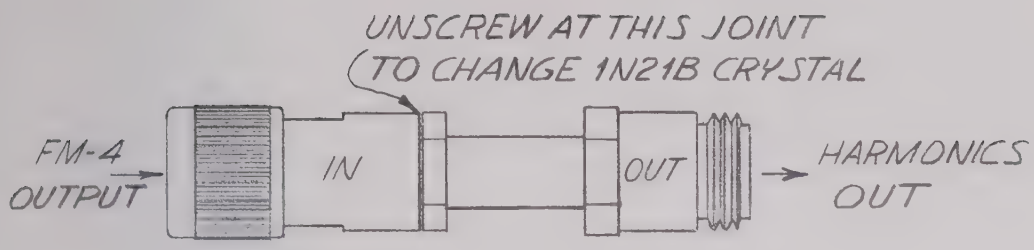


FIG. 1

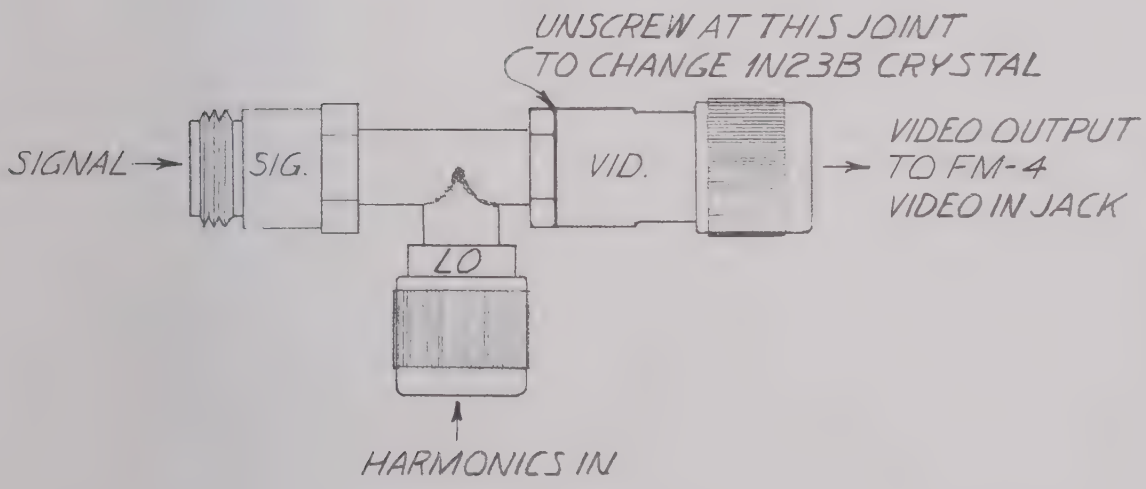


CONFIGURATION FOR MEASURING FREQUENCY OF SIGNAL - FIG. 2


UHF DRIVER
IN
FROM VHF DRIVER
(FM-3, AM-1, OR EQUIV.)
VIDEO IN
OUTPUT
FROM EXT. 1MC
SOURCE (IF INTERNAL
1MC NOT USED)
FM-4A
VID
LO
OUT
IN
SIG
HARMONIC GENERATOR
AND MIXER
FREQUENCY TO BE
MEASURED

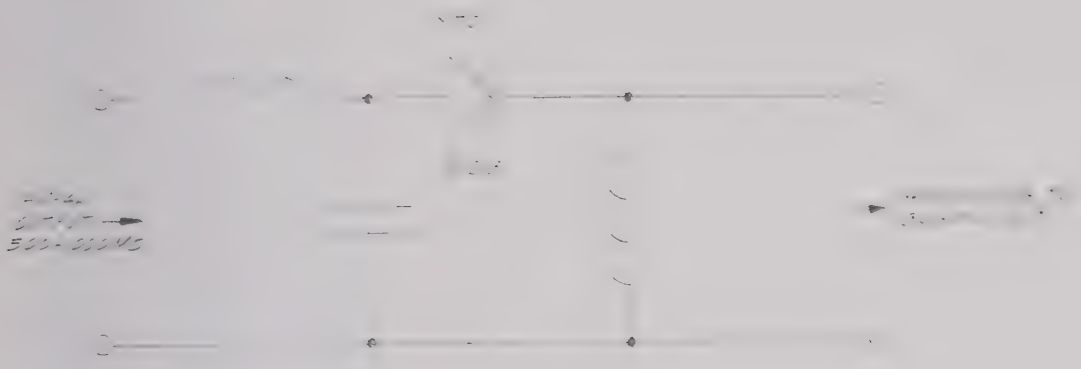


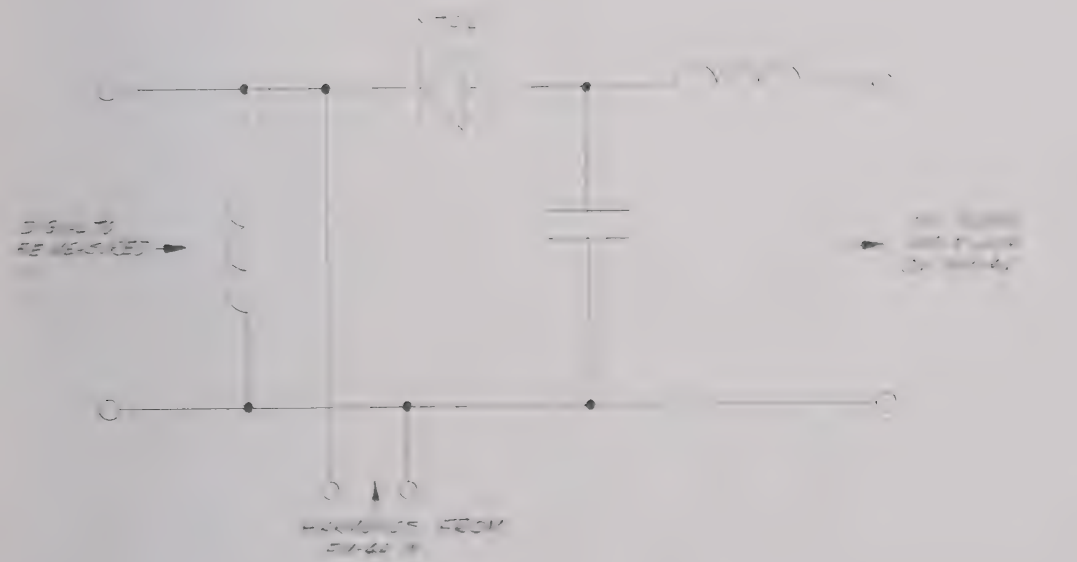
(a) HARMONIC GENERATOR SUB-ASSEMBLY

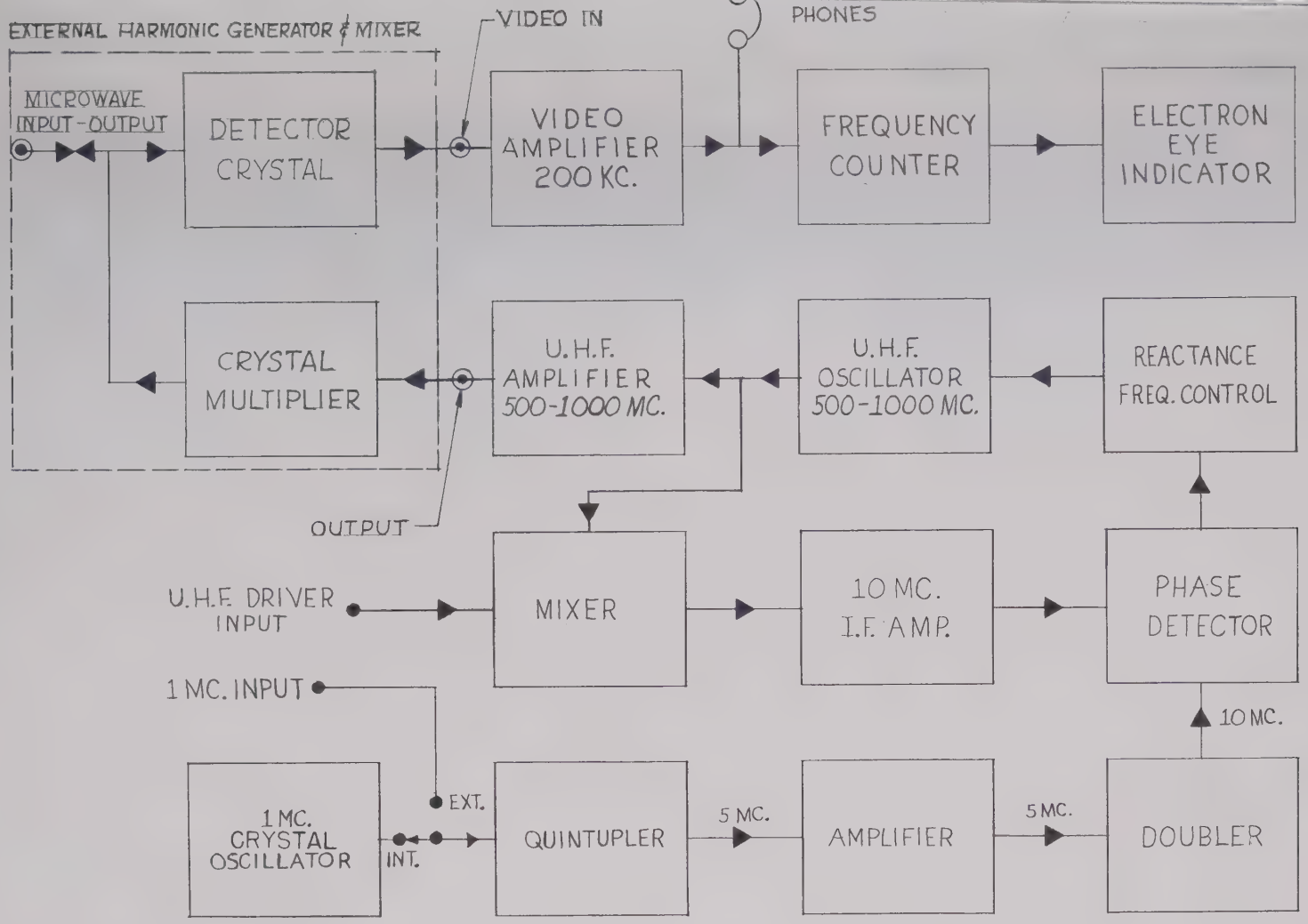


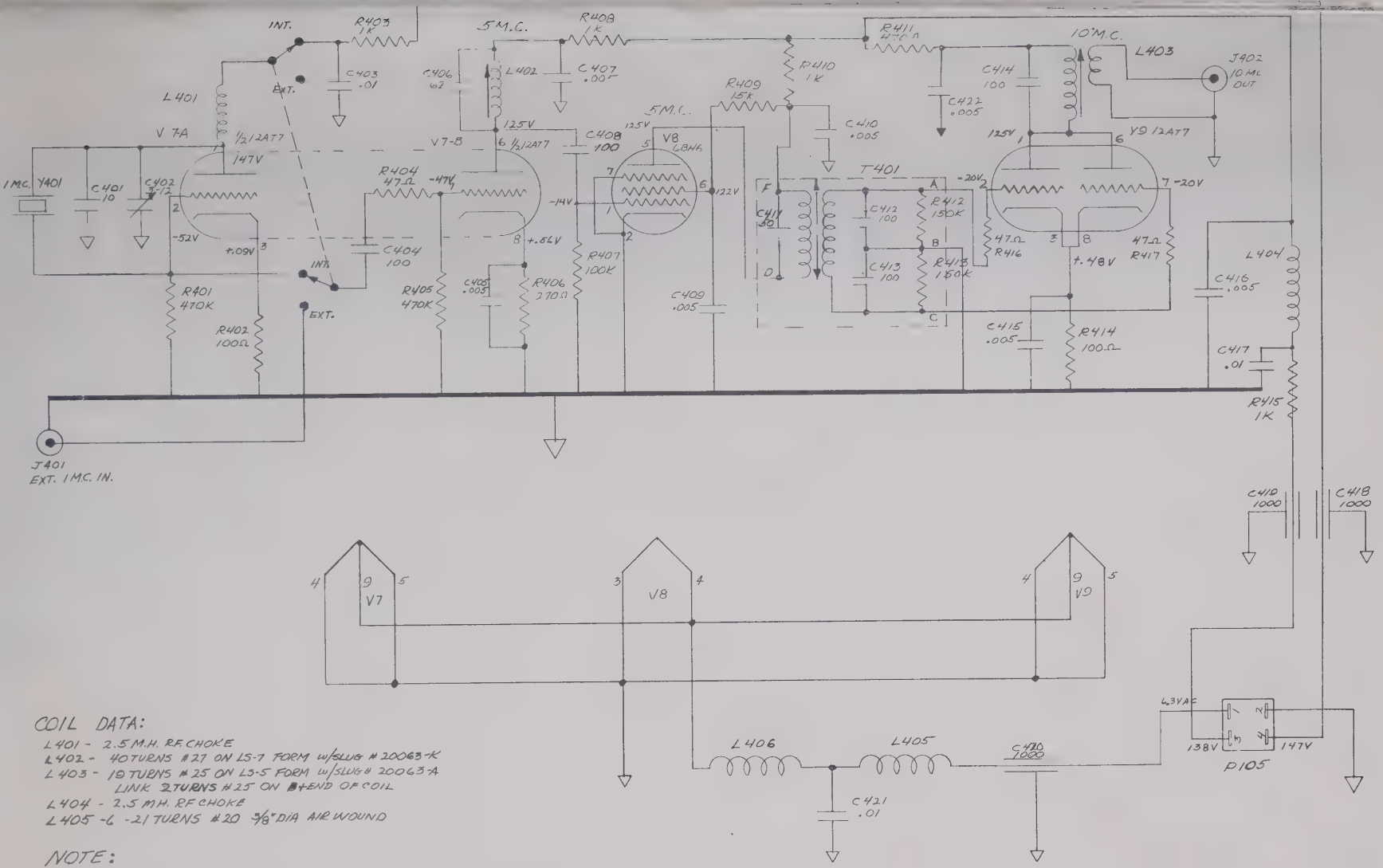
(b) MIXER SUB-ASSEMBLY

FIG-4






EXTERNAL HARMONIC GENERATOR & MIXER
MICROWAVE INPUT-OUTPUT
DETECTOR CRYSTAL
VIDEO IN
VIDEO AMPLIFIER 200 KC.
PHONES
FREQUENCY COUNTER
ELECTRON EYE INDICATOR
CRYSTAL MULTIPLIER
U.H.F. AMPLIFIER 500-1000 MC.
U.H.F. OSCILLATOR 500-1000 MC.
REACTANCE FREQ. CONTROL
OUTPUT
U.H.F. DRIVER INPUT
MIXER
10 MC. I.F. AMP.
PHASE DETECTOR
1 MC. INPUT
10 MC.
1 MC. CRYSTAL OSCILLATOR
EXT.
INT.
QUINTUPLER
5 MC.
AMPLIFIER
5 MC.
DOUBLER

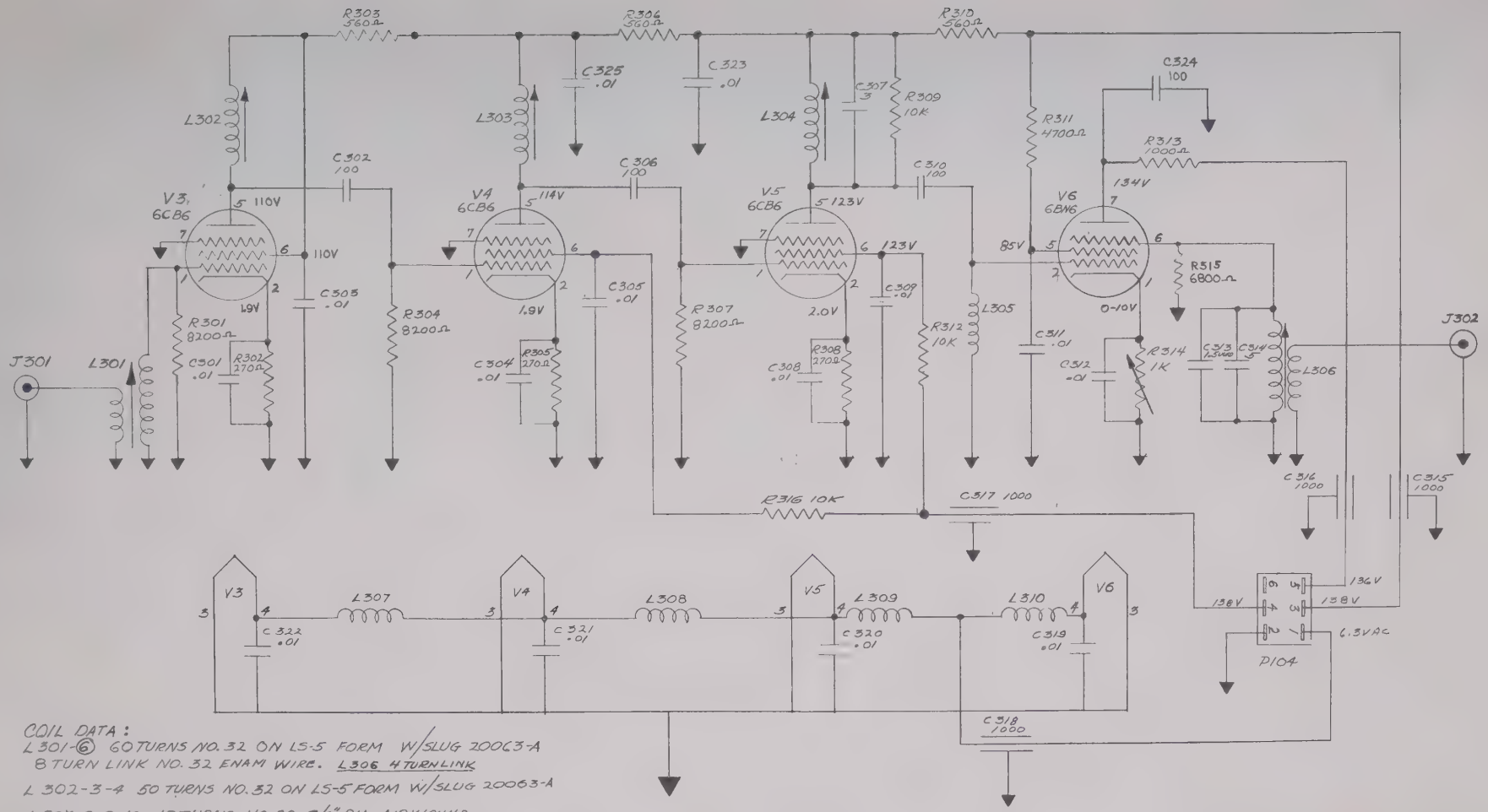


COIL DATA:

L401 - 2.5 M.H. RF CHOKE
L402 - 40 TURNS #27 ON LS-7 FORM W/SLUG # 20063-K
L403 - 10 TURNS #25 ON LS-5 FORM W/SLUG # 20063-A
LINK 2 TURNS #25 ON B+ END OF COIL
L404 - 2.5 MH. RF CHOKE
L405 - 6 - 21 TURNS #20 3/8" DIA AIR WOUND

NOTE:

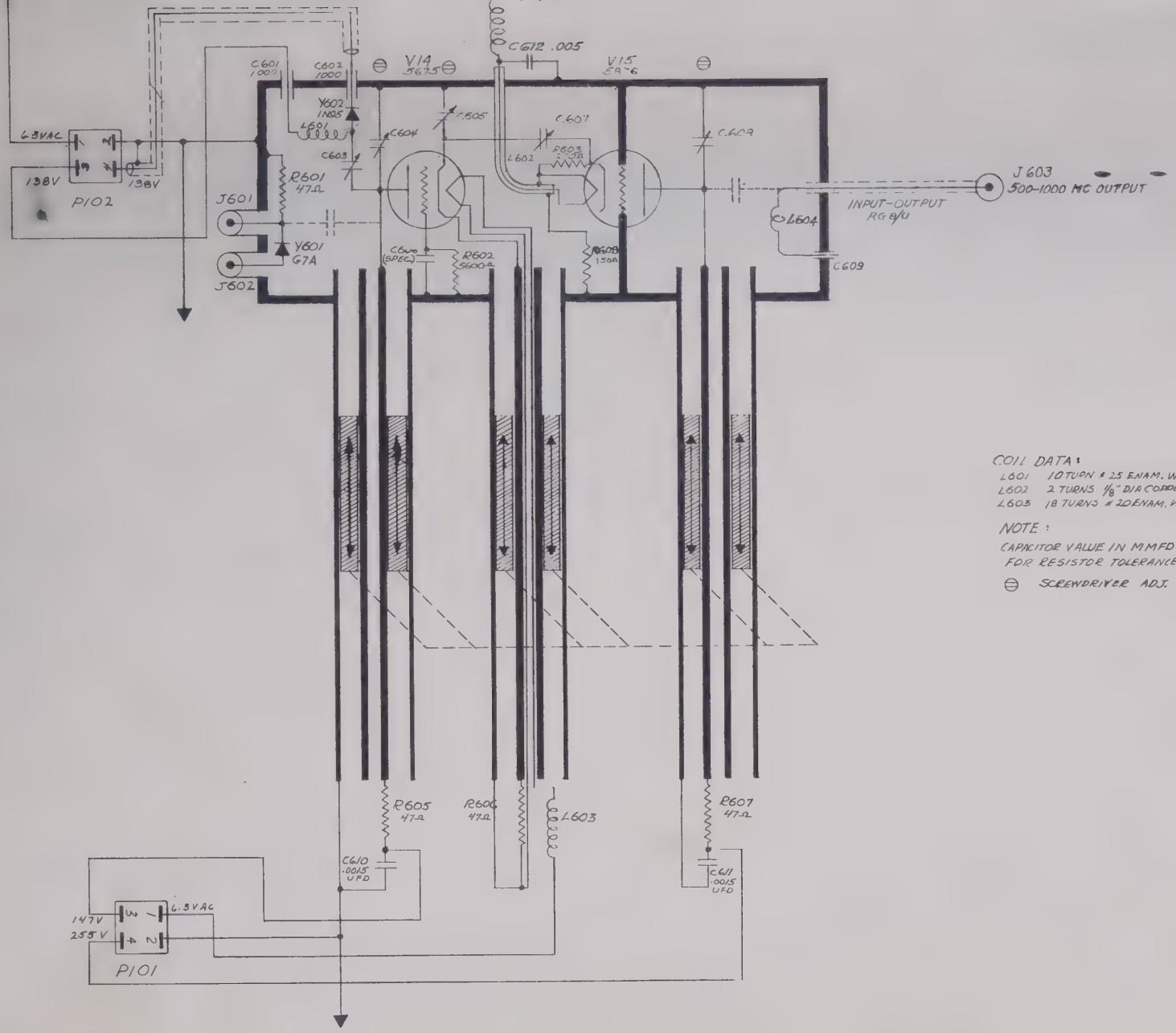
CAPACITORS MARKED IN DECIMALS ARE MFD UNLESS SPECIFIED
CAPACITORS MARKED IN WHOLE NUMBERS ARE MMFD UNLESS SPECIFIED
FOR RESISTOR WATTAGES & TOLERANCE REFER TO PARTS LIST



COIL DATA:
L301-6 60 TURNS NO. 32 ON LS-5 FORM W/SLUG 20063-A
8 TURN LINK NO. 32 ENAM WIRE. L306 4 TURN LINK
L 302-3-4 50 TURNS NO. 32 ON LS-5 FORM W/SLUG 20063-A
L 307-8-9-10 15 TURNS NO. 20 3/8" DIA AIR WOUND
L 305 2.5 MH RF CHOKE (SPECIAL)

NOTE:
CAPACITORS MARKED IN DECIMALS ARE MFD UNLESS SPECIFIED.
CAPACITORS MARKED IN WHOLE NUMBERS ARE MMFD UNLESS SPECIFIED.
FOR RESISTOR TOLERANCE & WATTAGE REFER TO PARTS LIST.

FIG. 8



COIL DATA:

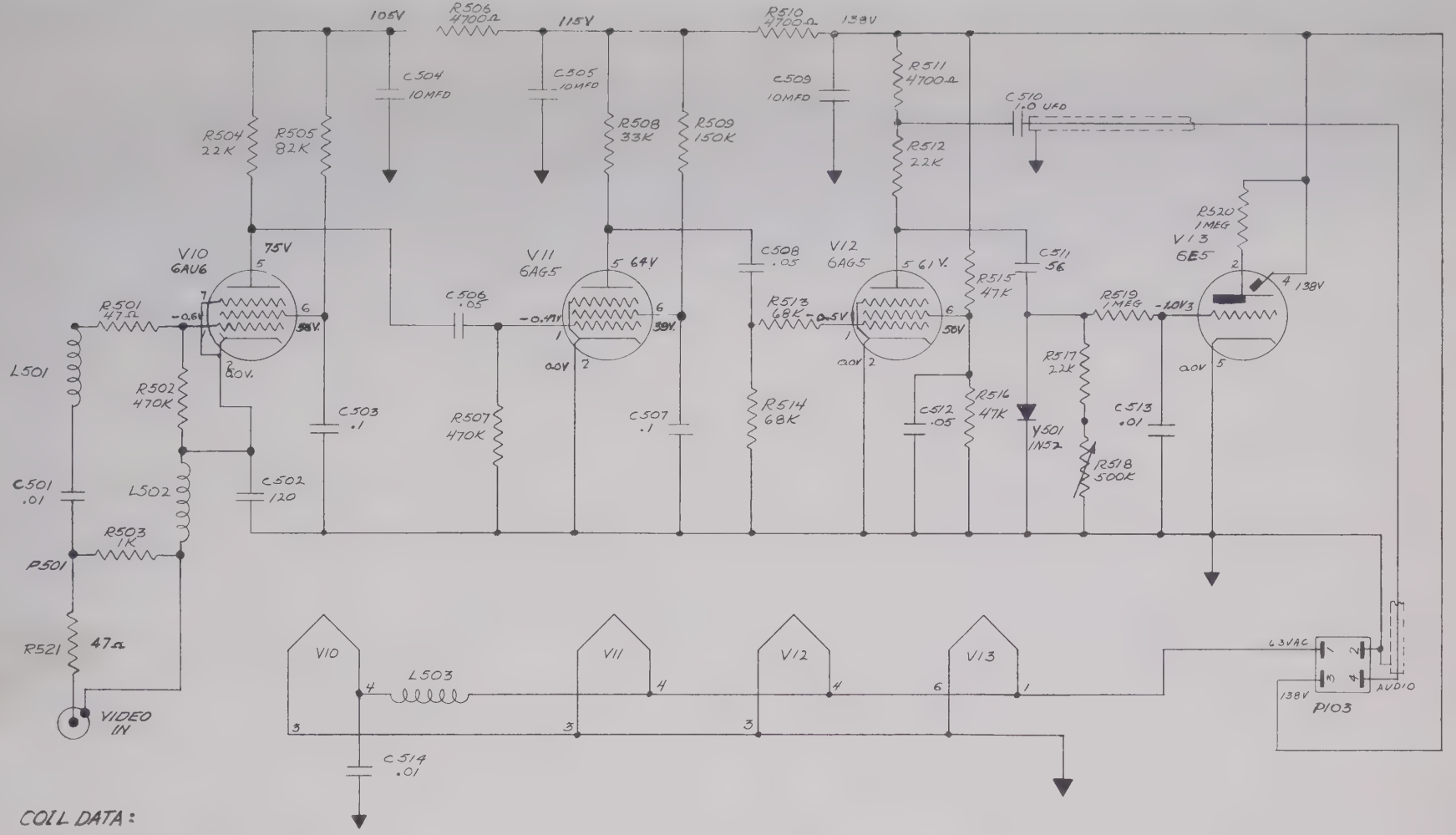
L601 10 TURN # 25 ENAM. WIRE ON 1/8" DIA BAKELITE ROD (D-126)
L602 2 TURNS 1/8" DIA COPPER TUBE 7/16" DIA INSIDE
L603 18 TURNS # 20 ENAM. WIRE WOUND ON 1 MEG 2W RESISTOR

NOTE:

CAPACITOR VALUE IN MMFD UNLESS SPECIFIED
FOR RESISTOR TOLERANCE & WATTAGE REFER TO PARTS LIST

⊖ SCREWDRIVER ADJ.

FIG. 9



COIL DATA:

L501-2-3 1 MEG RESISTOR WOUND WITH # 29 WIRE.

NOTE:

CAPACITORS MARKED IN DECIMALS ARE IN MFD UNLESS SPECIFIED
CAPACITORS MARKED IN WHOLE NUMBERS ARE IN MMFD UNLESS SPECIFIED
FOR RESISTOR TOLERANCE & WATTAGE REFER TO PARTS LIST
GRID VOLTAGE MEAS. W/VTVM
Y-5 GRID VOLTAGE TAKEN W/R518 MAX. POSITION

FIG. 10

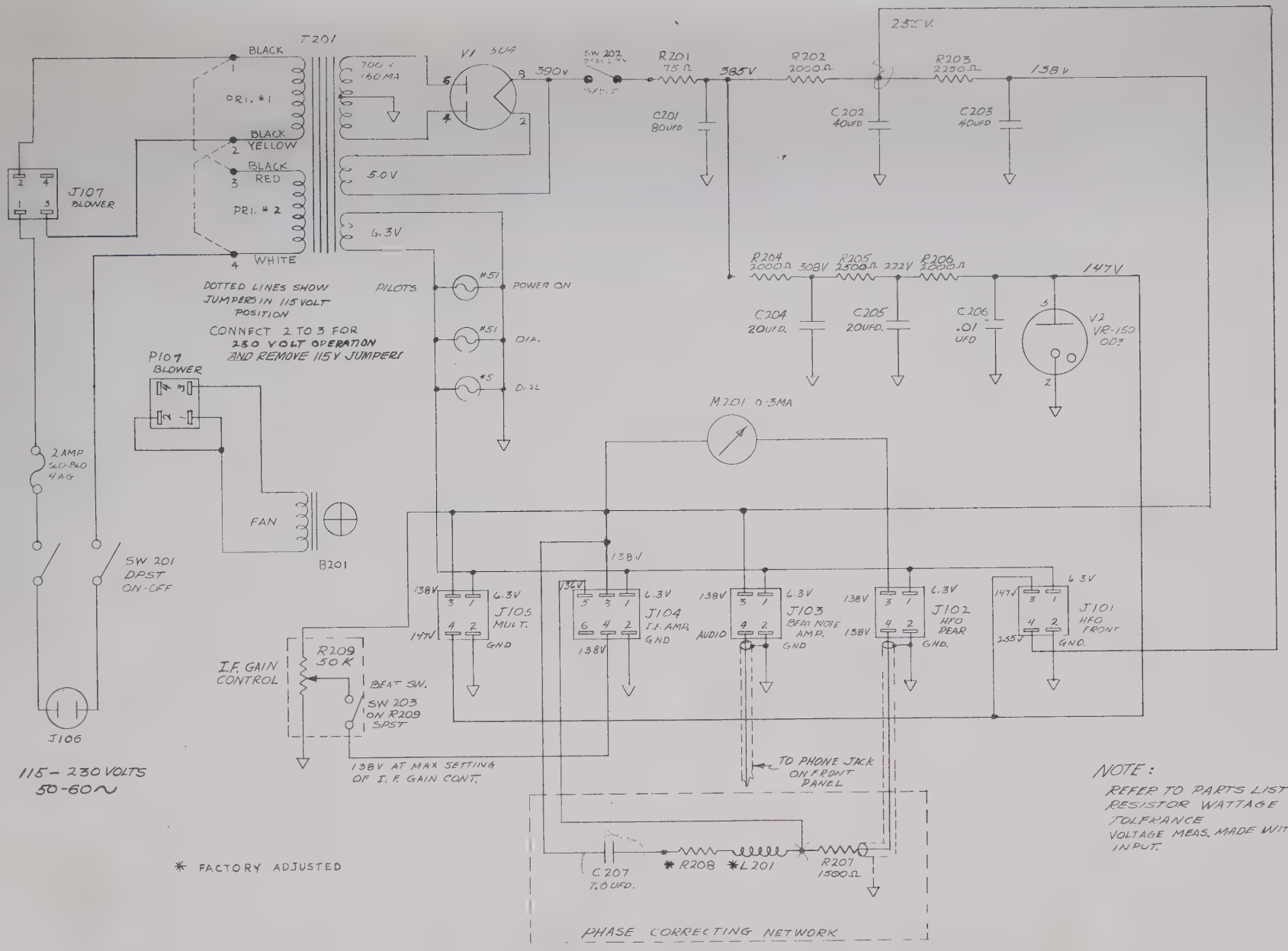

T201
BLACK
PRI. #1
BLACK
YELLOW
BLACK
RED
PRI. #2
WHITE
700 V
160 MA
5.0 V
6.3 V
V1 5U4
390 V
SW 202
R201
75 Ω
385 V
R202
2000 Ω
R203
2250 Ω
138 V
255 V
C201
80 UFD
C202
40 UFD
C203
40 UFD
R204
2000 Ω
308 V
R205
2500 Ω
222 V
R206
2000 Ω
147 V
C204
20 UFD.
C205
20 UFD.
C206
.01
UFD
V2
VR-150
007
M201 0-3MA
J107
BLOWER
P107
BLOWER
#51
POWER ON
#51
D/A.
#5
D/L
PILOTS
DOTTED LINES SHOW
JUMPERS IN 115 VOLT
POSITION
CONNECT 2 TO 3 FOR
230 VOLT OPERATION
AND REMOVE 115V JUMPER!
2 AMP
SLO-BLO
4AG
SW 201
DPST
ON-OFF
FAN
B201
J106
115 – 230 VOLTS
50-60 ~
J105
MULT.
J104
I.F. AMP.
J103
BEAT NOTE
AMP.
J102
HFO
REAR
J101
HFO
FRONT
GND
AUDIO
6.3V
I.F. GAIN
CONTROL
R209
50K
BEAT SW.
SW 203
ON R209
SPST
138V AT MAX SETTING
OF I.F. GAIN CONT.
TO PHONE JACK
ON FRONT
PANEL
C207
7.0 UFD.
*R208
*L201
R207
1500 Ω
PHASE CORRECTING NETWORK
* FACTORY ADJUSTED
NOTE:
REFER TO PARTS LIST FOR
RESISTOR WATTAGE AND
TOLERANCE
VOLTAGE MEAS. MADE WITH 115V
INPUT.

FIG. 11

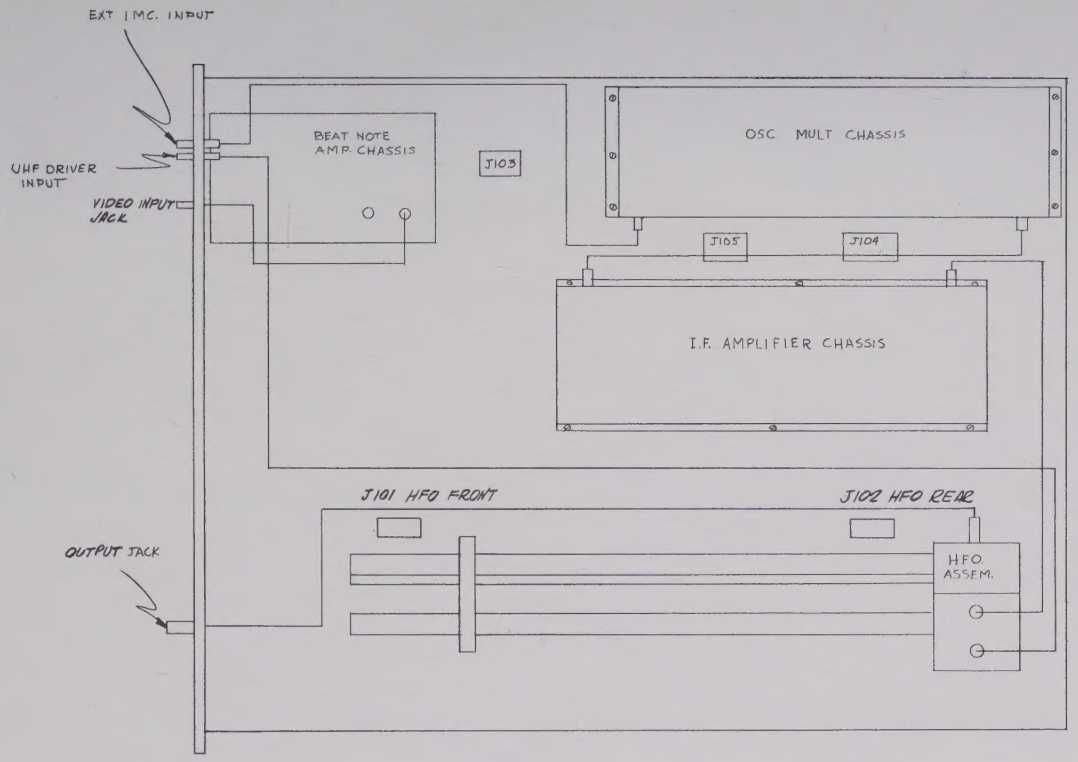

EXT I MC. INPUT
UHF DRIVER INPUT
VIDEO INPUT JACK
BEAT NOTE AMP. CHASSIS
J103
OSC. MULT CHASSIS
J105
J104
I.F. AMPLIFIER CHASSIS
J101 HFO FRONT
J102 HFO REAR
OUTPUT JACK
HFO. ASSEM.

FIG. 12